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Martini

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(54) **MAINTAINING IP TABLES**

(71) Applicant: **iboss, Inc.**, San Diego, CA (US)

(72) Inventor: **Paul Michael Martini**, San Diego, CA (US)

(73) Assignee: **iboss, Inc.**, San Diego, CA (US)

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G06F 15/173 (2006.01)
H04L 12/24 (2006.01)
H04L 29/12 (2006.01)

(52) **U.S. Cl.**
CPC ***H04L 41/5054*** (2013.01); ***H04L 61/1511*** (2013.01)

(58) **Field of Classification Search**
USPC 709/223, 245, 203; 707/10, 769
See application file for complete search history.

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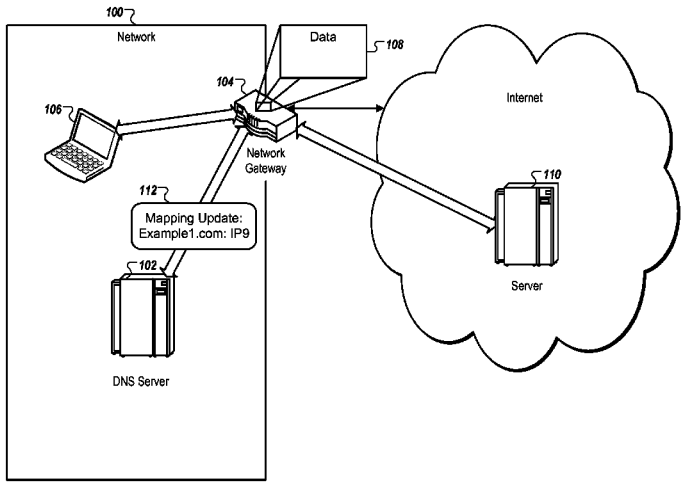
Primary Examiner — Tammy Nguyen
(74) *Attorney, Agent, or Firm* — Fish & Richardson P.C.

(57) **ABSTRACT**

Data including a set of one or more resources and one or more associated IP addresses is updated based on monitored DNS responses. A request is received from a client device for a resource identified by an IP address. The IP address is matched to one of the IP addresses in the set of one or more IP addresses. A particular resource associated with the matched IP address is identified. A particular network policy that applies is identified. The identified particular network policy is applied to the received request.

16 Claims, 7 Drawing Sheets



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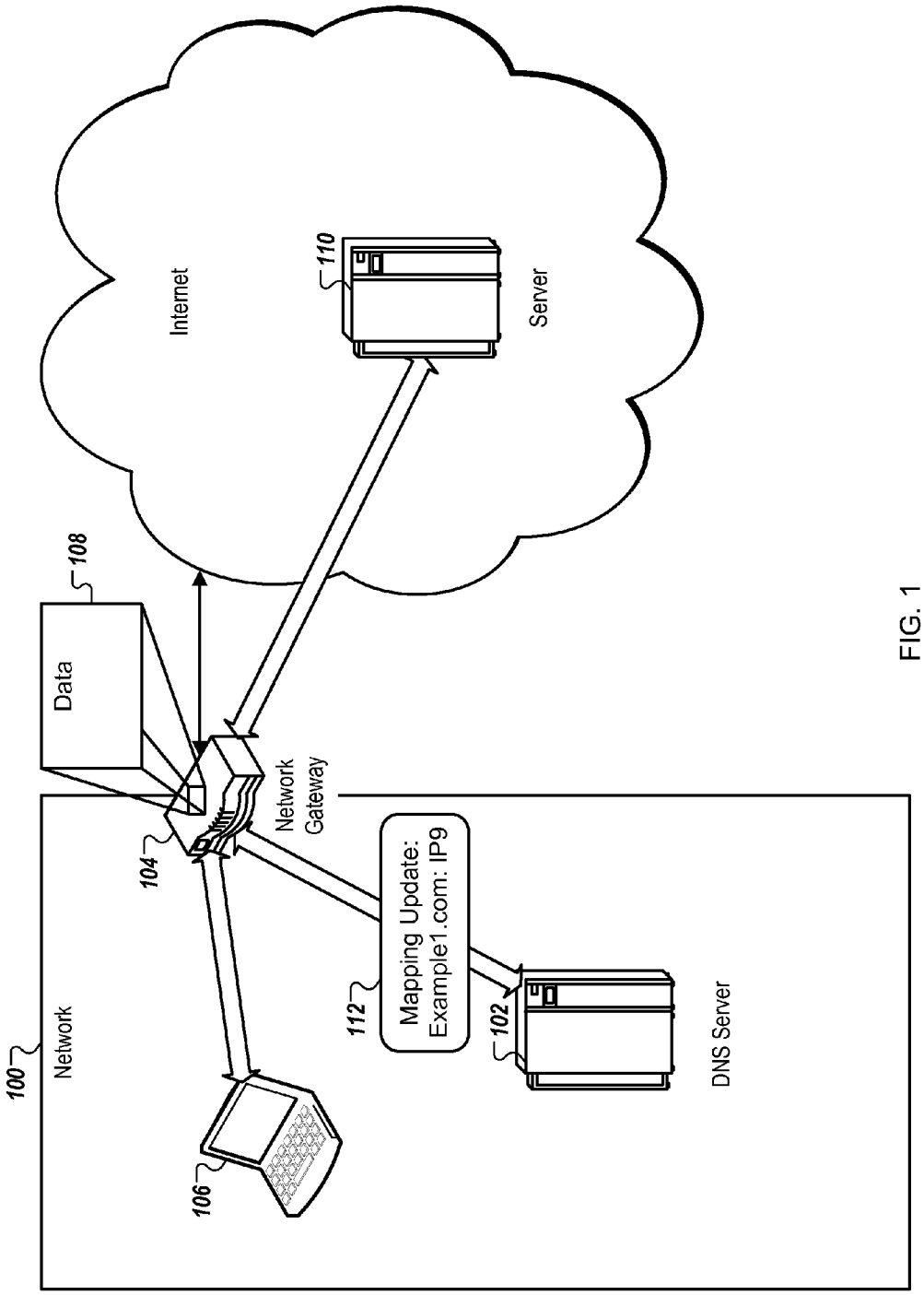
Internet
110
Server
108
Data
Network Gateway
104
Mapping Update:
Example1.com: IP9
112
102
DNS Server
100
Network
106

FIG. 1

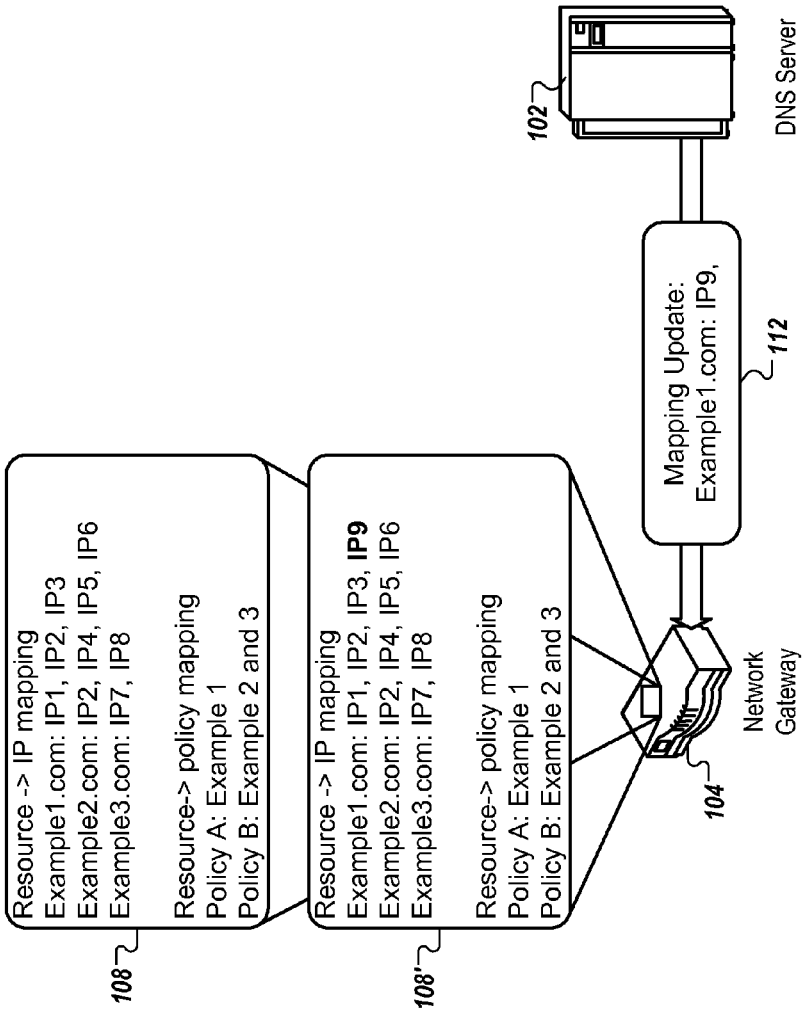
Resource -> IP mapping
Example1.com: IP1, IP2, IP3
Example2.com: IP2, IP4, IP5, IP6
Example3.com: IP7, IP8
Resource-> policy mapping
Policy A: Example 1
Policy B: Example 2 and 3
108
Resource -> IP mapping
Example1.com: IP1, IP2, IP3, IP9
Example2.com: IP2, IP4, IP5, IP6
Example3.com: IP7, IP8
Resource-> policy mapping
Policy A: Example 1
Policy B: Example 2 and 3
108'
Mapping Update:
Example1.com: IP9,
112
102
DNS Server
104
Network
Gateway

FIG. 2

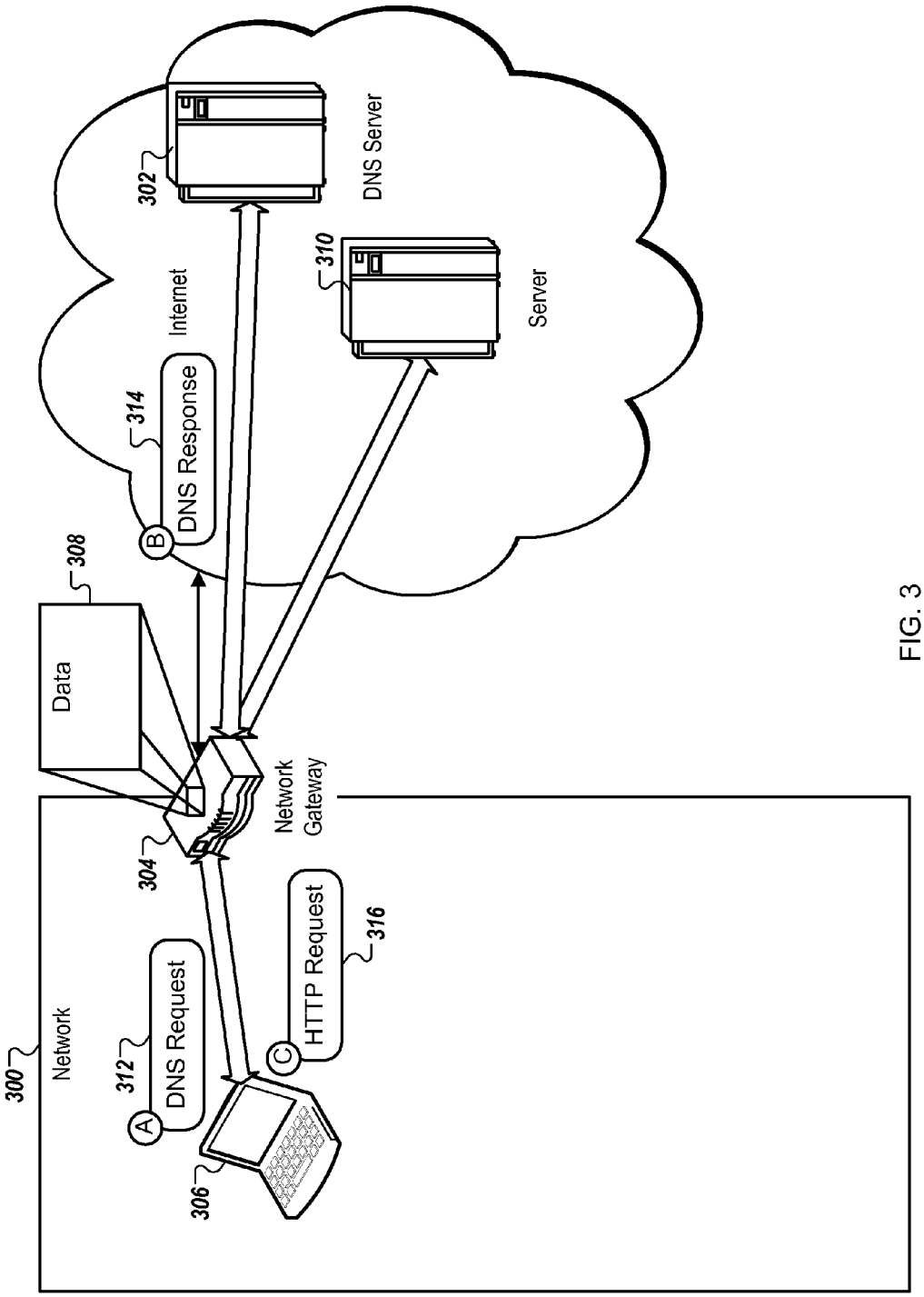
300
Network
312
DNS Request
A
306
304
Network Gateway
316
HTTP Request
C
308
Data
314
DNS Response
B
Internet
302
DNS Server
310
Server

FIG. 3

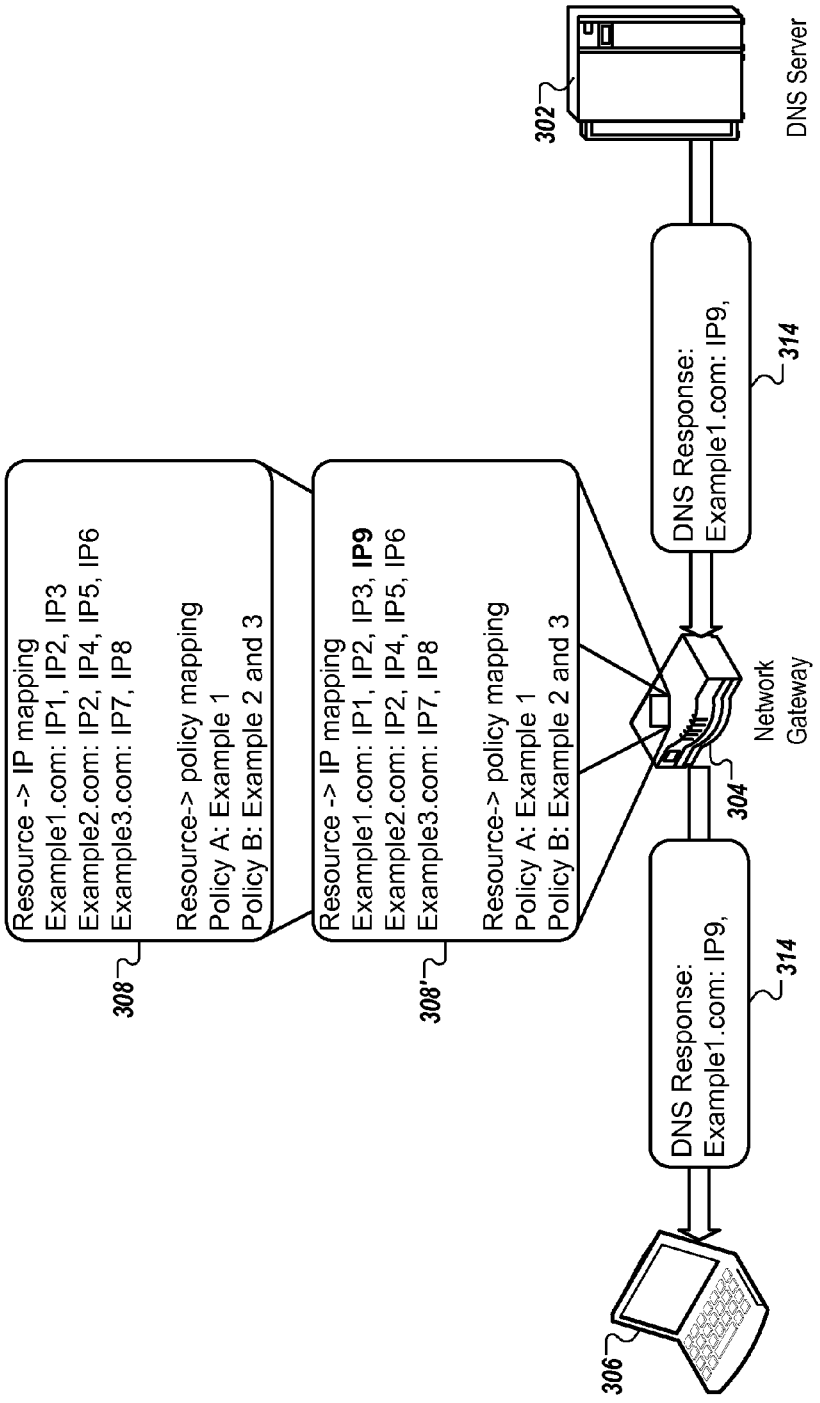
302
DNS Server
DNS Response:
Example1.com: IP9,
314
DNS Response:
Example1.com: IP9,
314
Network
Gateway
304
306
Resource -> IP mapping
Example1.com: IP1, IP2, IP3
Example2.com: IP2, IP4, IP5, IP6
Example3.com: IP7, IP8
Resource-> policy mapping
Policy A: Example 1
Policy B: Example 2 and 3
308
Resource -> IP mapping
Example1.com: IP1, IP2, IP3, IP9
Example2.com: IP2, IP4, IP5, IP6
Example3.com: IP7, IP8
Resource-> policy mapping
Policy A: Example 1
Policy B: Example 2 and 3
308'

FIG. 4

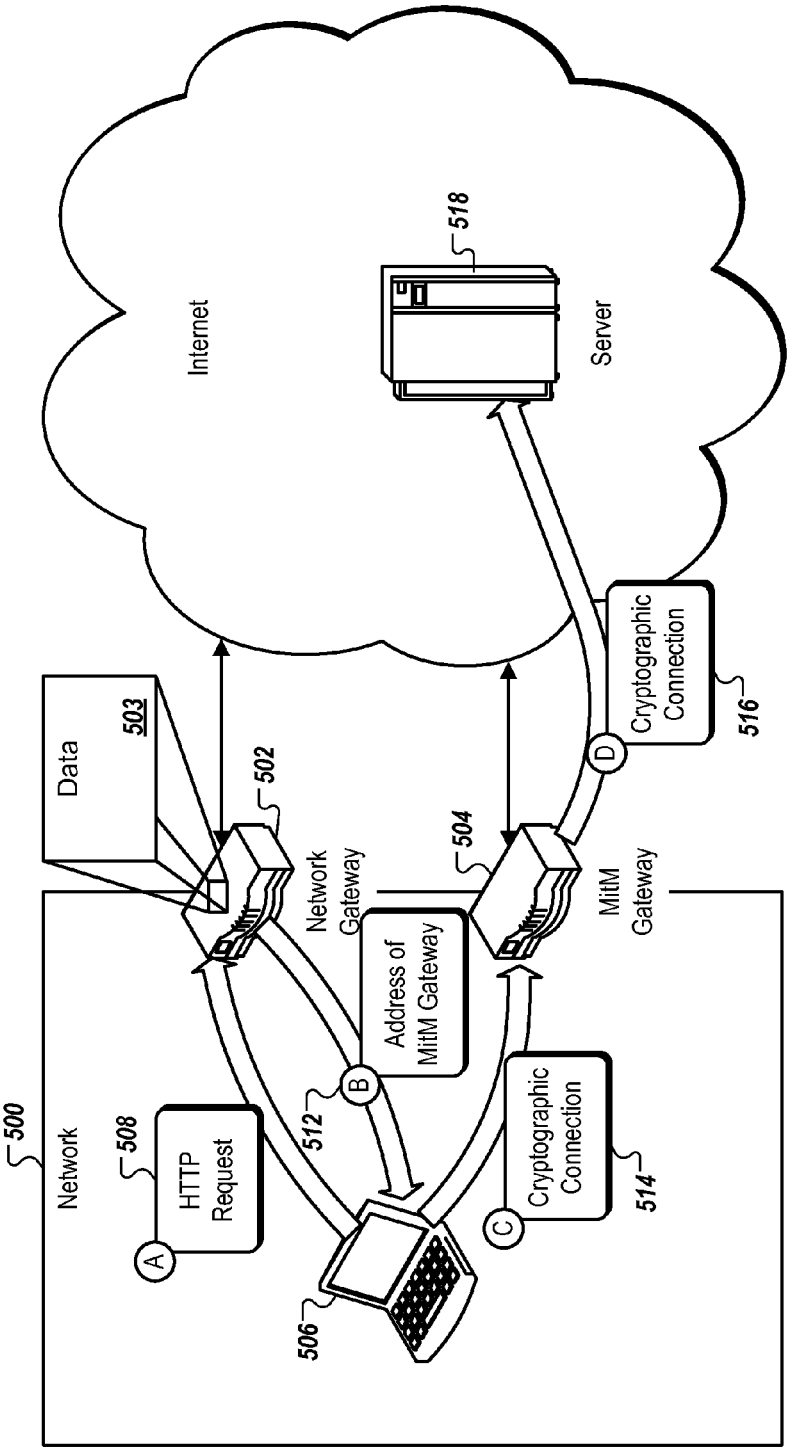
Internet
518
Server
Data
503
502
Network Gateway
504
MitM Gateway
Cryptographic Connection
516
D
Address of MitM Gateway
B
512
500
Network
508
HTTP Request
A
506
C
Cryptographic Connection
514

FIG. 5

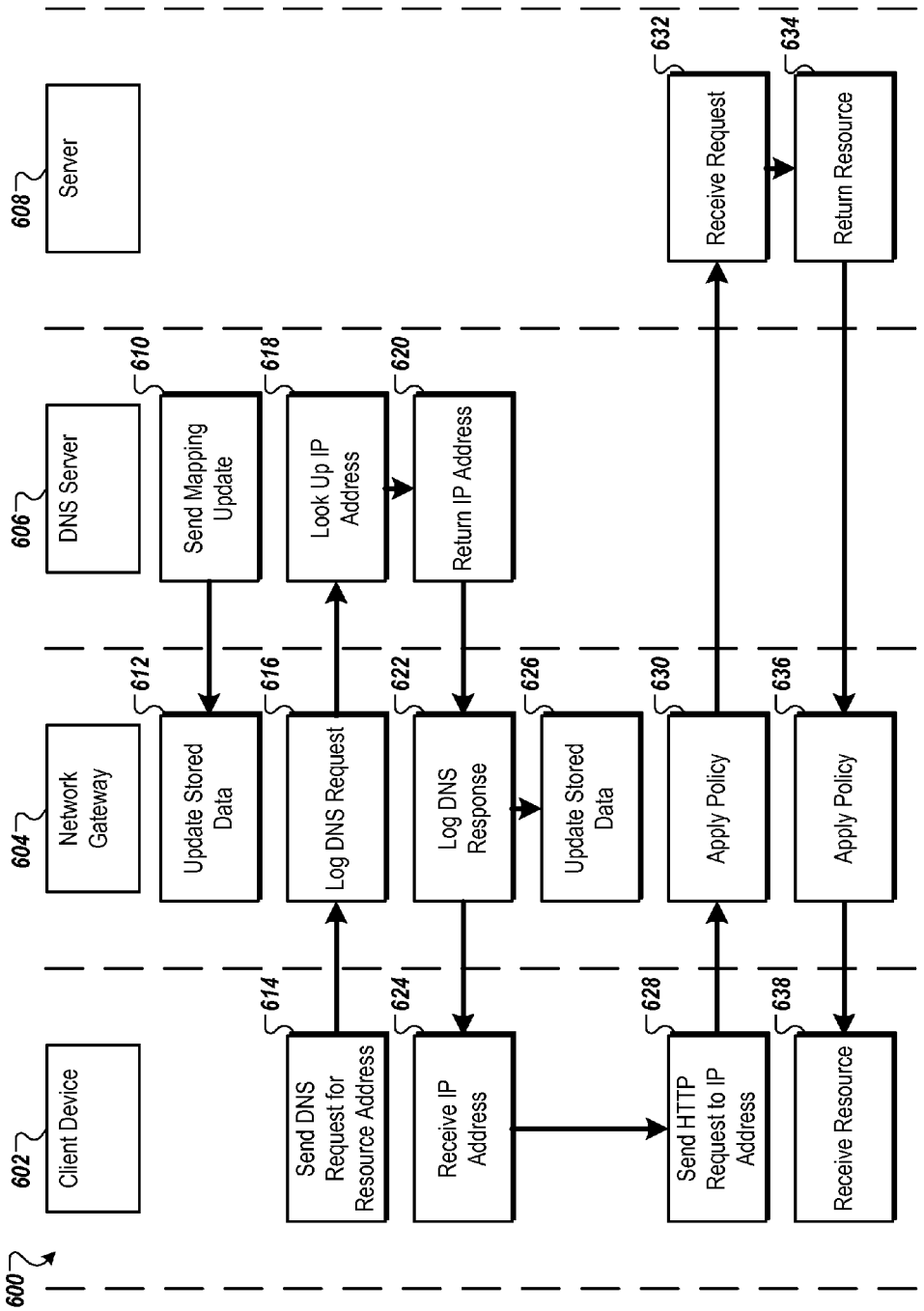
600
602
Client Device
604
Network Gateway
606
DNS Server
608
Server
610
Send Mapping Update
612
Update Stored Data
614
Send DNS Request for Resource Address
616
Log DNS Request
618
Look Up IP Address
620
Return IP Address
622
Log DNS Response
624
Receive IP Address
626
Update Stored Data
628
Send HTTP Request to IP Address
630
Apply Policy
632
Receive Request
634
Return Resource
636
Apply Policy
638
Receive Resource

FIG. 6

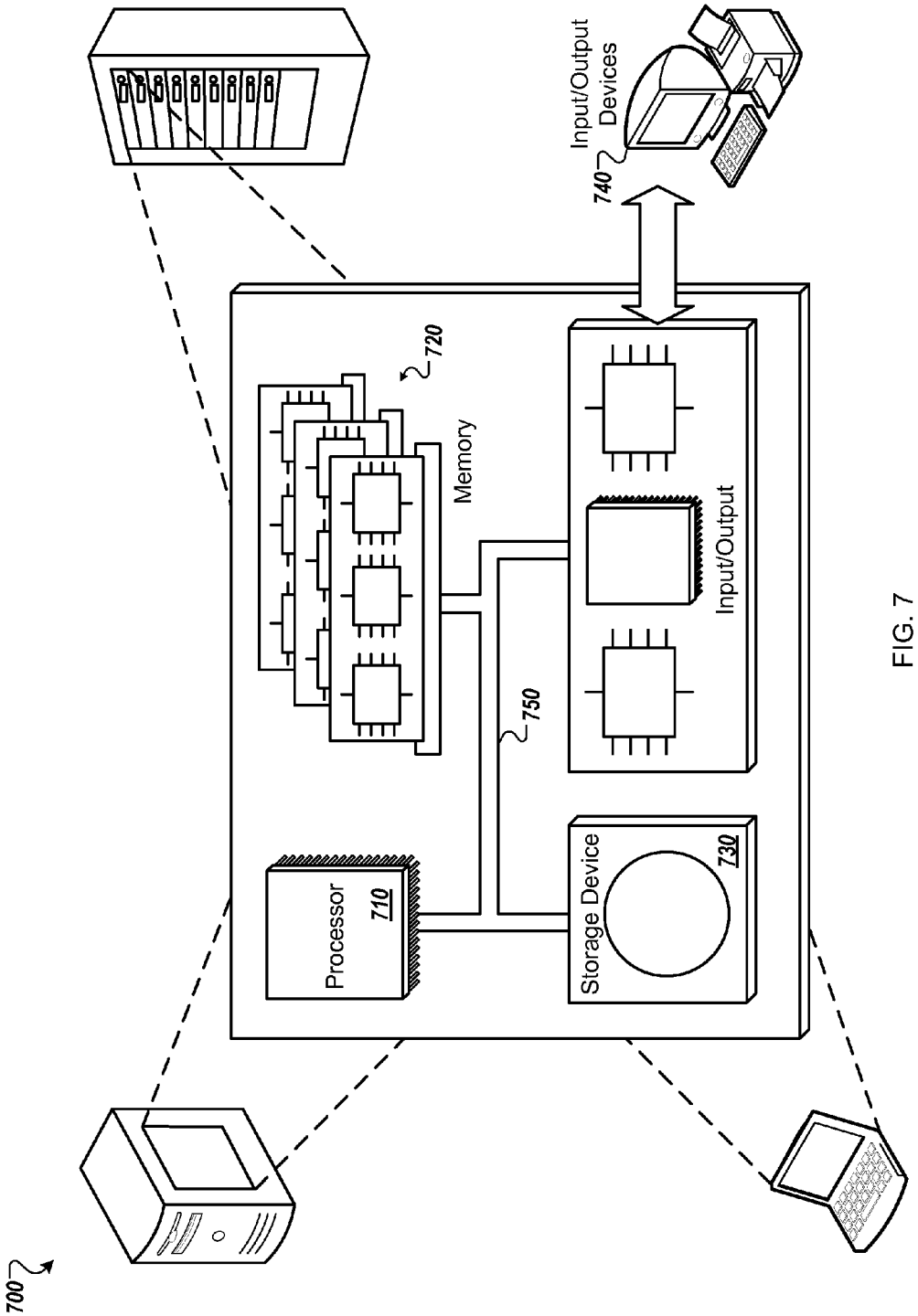
Input/Output Devices
740
720
Memory
Input/Output
750
Processor
710
Storage Device
730
700

FIG. 7

MAINTAINING IP TABLES

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation application of and claims priority to U.S. application Ser. No. 14/280,488, filed on May 16, 2014.

BACKGROUND

The present document relates to computer networking. A computer network is a collection of computers and other hardware interconnected by communication channels that allow sharing of resources and information. Communication protocols define the rules and data formats for exchanging information in a computer network. Transport Layer Security (TLS) and Secure Socket Layer (SSL) are two examples of cryptographic communication protocols that provide communication security by allowing devices to exchange encrypted, as opposed to plaintext, messages.

SUMMARY

In one aspect, a method is performed by data processing apparatus. The method includes maintaining (i) first data that identifies a set of one or more resources to which a policy of a network applies, and (ii) second data that identifies a set of one or more stored Internet Protocol (IP) addresses, and (iii) third data that associates each resource in the set with one or more IP addresses in the set of IP addresses. The method further includes monitoring DNS responses. The method further includes generating, from the monitored DNS responses, (i) fourth data that identifies a second new resource, and (ii) fifth data that identifies one or more second new IP addresses, and (iii) sixth data that associates the second new resource with one or more second new IP addresses. The method further includes updating the first data, based on the fourth data, to include the new resource in the set of one or more resources. The method further includes updating the second data, based on the fifth data, to include the one or more new IP addresses in the set of one or more IP addresses. The method further includes updating the third data, based on the sixth data, to update the associations between the set of resources and the set of IP addresses. The method further includes intercepting a request from a client device on the network for a requested resource identified by a requested IP address. The method further includes determining that the requested IP address matches one of the IP addresses in the set of IP addresses. The method further includes identifying a particular resource in the set of resources that is associated with the requested IP address. The method further includes identifying a particular policy of the network that applies to the particular resource. The method further includes applying the particular policy to the request.

Implementations can include any, all, or none of the following features. To apply the particular policy to the request, the data processing apparatus are configured to inspect communication between the client and a server serving the requested resource. Only request that have an applied policy are inspected. The DNS server is hosted on the network. The DNS server is under the same administrative control as the network. The method including receiving, from a domain name system (DNS) server, (i) seventh data that identifies a new resource, (ii) eighth data that identifies one or more new IP addresses, and (iii) ninth data that associates the new resource with one or more new IP addresses; updating the first data, based on the seventh data, to include the second new resource in the set of one or more resources; updating the second data, based on the eighth data, to include the one or more second new IP addresses in the set of one or more IP addresses; and updating the third data, based on the ninth data, to update the associations between the set of resources and the set of IP addresses. The DNS responses are received from DNS servers outside of the network. The data apparatus include a plurality of hardware devices, each hardware device including a separate processor and memory unit; wherein a first hardware device is configured to: route traffic to and from client devices on the network into and out of the network; maintain (i) first data that identifies a set of one or more resources to which a policy of a network applies, and (ii) second data that identifies a set of one or more stored Internet Protocol (IP) addresses, and (iii) third data that associates each resource in the set with one or more IP addresses in the set of IP addresses; receive, from a domain name system (DNS) server, (i) fourth data that identifies a new resource, (ii) fifth data that identifies one or more new IP addresses, and (iii) sixth data that associates the new resource with one or more new IP addresses; update the first data, based on the fourth data, to include the new resource in the set of one or more resources; update the second data, based on the fifth data, to include the one or more new IP addresses in the set of one or more IP addresses; update the third data, based on the sixth data, to update the associations between the set of resources and the set of IP addresses; intercept a request from a client device on the network for a requested resource identified by a requested IP address; determine that the requested IP address matches one of the IP addresses in the set of IP addresses; identify a particular resource in the set of resources that is associated with the requested IP address; identify a particular policy of the network that applies to the particular resource; and wherein a second hardware device is configured to apply the particular policy to the request. The resource is identified in the first data by the resource's Uniform Resource Locator (URL).

In one aspect, a method is performed by data processing apparatus. The method includes maintaining information includes (i) a set of one or more resources to which a network policy applies, and (ii) a set of one or more Internet Protocol (IP) addresses. Each resource is associated with one or more of the IP addresses. The method further includes monitoring DNS responses. The method further includes generating, from the monitored DNS responses, data identifying (i) a new resource, or (ii) one or more new IP addresses, or (iii) both a new resource and one or more new IP addresses. Each new IP address is associated with either a resource in the set of one or more resources, or the new resource. The method further includes updating the maintained information based on the data received from the DNS. The method further includes receiving a request from a client device on the network for a requested resource identified by a requested IP address. The method further includes determining that the requested IP address matches one of the IP addresses in the set of one or more IP addresses. The method further includes identifying a particular resource associated with the matched IP address. The method further includes identifying a particular network policy applies. The method further includes applying the identified particular network policy to the received request.

Implementations can include any, all, or none of the following features. To apply the particular policy to the request, the data processing apparatus are configured to inspect communication between the client and a server serving the requested resource. Only request that have an applied policy are inspected. The DNS server is hosted on the network. The

DNS server is under the same administrative control as the network. The method including receiving, from a domain name service (DNS) server, data identifying (i) a new resource, or (ii) one or more new IP addresses, or (iii) both a new resource and one or more new IP addresses, wherein each new IP address is associated with either a resource in the set of one or more resources, or the new resource; and updating the maintained information based on the data generated from the DNS responses. The DNS responses are received from DNS servers outside of the network. The data apparatus include a plurality of hardware devices, each hardware device including a separate processor and memory unit; wherein a first hardware device is configured to: route traffic to and from client devices on the network into and out of the network; and maintain information including (i) a set of one or more resources to which a network policy applies, and (ii) a set of one or more Internet Protocol (IP) addresses, wherein each resource is associated with one or more of the IP addresses; monitor DNS responses; generate, from the monitored DNS responses, data identifying (i) a new resource, or (ii) one or more new IP addresses, or (iii) both a new resource and one or more new IP addresses, wherein each new IP address is associated with either a resource in the set of one or more resources, or the new resource; update the maintained information based on the data received from the DNS; receive a request from a client device on the network for a requested resource identified by a requested IP address; determine that the requested IP address matches one of the IP addresses in the set of one or more IP addresses; identify a particular resource associated with the matched IP address; and identify a particular network policy; and wherein a second hardware device is configured to apply the particular policy to the request. The resource is identified in the information by the resource's Uniform Resource Locator (URL).

In one aspect, a system includes one or more processors configured to execute computer program instructions. The system further includes computer storage media encoded with computer program instructions that, when executed by one or more processors, cause data processing apparatus to perform operation includes maintaining (i) first data that identifies a set of one or more resources to which a policy of a network applies, and (ii) second data that identifies a set of one or more stored Internet Protocol (IP) addresses, and (iii) third data that associates each resource in the set with one or more IP addresses in the set of IP addresses. The operations further include monitoring DNS responses. The operations further include generating, from the monitored DNS responses, (i) seventh data that identifies a second new resource, and (ii) eighth data that identifies one or more second new IP addresses, and (iii) ninth data that associates the second new resource with one or more second new IP addresses. The operations further include updating the first data, based on the fourth data, to include the new resource in the set of one or more resources. The operations further include updating the second data, based on the fifth data, to include the one or more new IP addresses in the set of one or more IP addresses. The operations further include updating the third data, based on the sixth data, to update the associations between the set of resources and the set of IP addresses. The operations further include intercepting a request from a client device on the network for a requested resource identified by a requested IP address. The operations further include determining that the requested IP address matches one of the IP addresses in the set of IP addresses. The operations further include identifying a particular resource in the set of resources that is associated with the requested IP address. The operations further include identifying a particular policy of the network that applies to the particular resource. The operations further include applying the particular policy to the request.

Implementations can include any, all, or none of the following features. Applying the particular policy to the request includes inspecting communication between the client and a server serving the requested resource. Only request that have an applied policy are inspected. The DNS server is hosted on the network. The DNS server is under the same administrative control as the network. The operations include receiving, from a domain name system (DNS) server, (i) fourth data that identifies a new resource, (ii) fifth data that identifies one or more new IP addresses, and (iii) sixth data that associates the new resource with one or more new IP addresses; updating the first data, based on the seventh data, to include the second new resource in the set of one or more resources; updating the second data, based on the eighth data, to include the one or more second new IP addresses in the set of one or more IP addresses; and updating the third data, based on the ninth data, to update the associations between the set of resources and the set of IP addresses. The DNS responses are received from DNS servers outside of the network. The data apparatus include a plurality of hardware devices, each hardware device including a separate processor and memory unit; wherein a first hardware device is configured to: route traffic to and from client devices on the network into and out of the network; maintain (i) first data that identifies a set of one or more resources to which a policy of a network applies, and (ii) second data that identifies a set of one or more stored Internet Protocol (IP) addresses, and (iii) third data that associates each resource in the set with one or more IP addresses in the set of IP addresses; monitor DNS responses; generate, from the monitored DNS responses, (i) seventh data that identifies a second new resource, and (ii) eighth data that identifies one or more second new IP addresses, and (iii) ninth data that associates the second new resource with one or more second new IP addresses; update the first data, based on the fourth data, to include the new resource in the set of one or more resources; update the second data, based on the fifth data, to include the one or more new IP addresses in the set of one or more IP addresses; update the third data, based on the sixth data, to update the associations between the set of resources and the set of IP addresses; intercept a request from a client device on the network for a requested resource identified by a requested IP address; determine that the requested IP address matches one of the IP addresses in the set of IP addresses; identify a particular resource in the set of resources that is associated with the requested IP address; identify a particular policy of the network that applies to the particular resource; and wherein a second hardware device is configured to apply the particular policy to the request. The resource is identified in the first data by the resource's Uniform Resource Locator (URL).

Implementations can include any, all, or none of the following features.

The systems and processes described here may be used to provide a number of potential advantages. For example, by receiving updates from a domain name system (DNS) server, a network device can keep up-to-date mappings of domain names to internet protocol (IP) addresses. The network device may also track DNS messages on a network to keep up-to-date mappings of domain names to internet protocol (IP) addresses. These mappings may be accurate even for domain names that have many IP address and/or that share IP addresses across different domains. Changes to DNS information can be quickly reflected in the mappings.

Other features, aspects and potential advantages will be apparent from the accompanying description and figures.

DESCRIPTION OF DRAWINGS

FIG. **1** is a block diagram of an example network with a DNS server.

FIG. **2** is a block diagram of an example updated domain name to IP address mapping.

FIG. **3** is a block diagram of an example network and a remote DNS server.

FIG. **4** is a block diagram of an example updated domain name to IP address mapping.

FIG. **5** is a block diagram of an example network that is applying a policy to a request.

FIG. **6** is a swim-lane diagram of an example process for keeping a mapping of domain names to IP addresses

FIG. **7** is a schematic diagram that shows an example of a computing system.

Like reference symbols in the various drawings indicate like elements

DETAILED DESCRIPTION

A network device, such as a network gateway, can be tasked to apply policies of the network to requests on the network. However, these policies may be assigned to internet domains or subdomains, and many or all of the requests may contain only an IP address that corresponds to the domain or subdomain. In order to apply the policies to the requests, the network device can maintain and update a mapping of domains to IP addresses.

To update the mapping, one or more different techniques may be used. In one technique, the network can host a DNS server, which can be in communication with an off-network DNS server. This DNS server can be configured to generate update messages that contain IP addresses assigned domains associated with policies of the network. In another technique, the network device can monitor DNS requests and responses on the network. When a matching DNS request and response are identified, their associated domain and IP address can be added to the mapping maintained by the network device.

FIG. **1** is a block diagram of an example network **100** with a DNS server **102**. The network **100** includes a network gateway **104** and a client device **106**, which represents any appropriate computing devices capable of browsing resources inside or outside of the network **100**. While not shown for clarity's sake, the network **100** can include other elements including, but not limited to, wireless and/or wired access points, file and/or application servers, routers, and network cables, as well as additional client devices and network gateways.

The network **100** can be configured to route some or all of the traffic into and out of the network **100** through the gateway **104**. For example, the gateway **104** may inspect network traffic to enforce security policies, prevent malicious software from entering the network, etc. Additionally, the gateway **104** may provide directory services for the clients of the network **100** (e.g., ApacheDS, Active Directory), may apply policies (e.g., security policies) to devices on the network **100**, and may assign the client device **106** to a subnet.

To enforce the policies of the network **100**, the gateway **104** may maintain data **108** that identifies a set of one or more resources to which a policy of a network applies, identifies a set of one or more stored Internet Protocol (IP) addresses, and associates each resource in the set with one or more IP addresses in the set of IP addresses. The data **108** may include, for example, iptables or other known or custom data structures. When the network gateway **104** receives a message, for example a request from the client device **106** for a resource at an IP address of the server **110**, the network gateway **104** can determine if the IP addresses matches a stored IP address in the data **108**. If the match is found, the network gateway **104** can identify an associated resource stored in the data **108**. Once an associated resource is identified, the network gateway **104** can determine if one or more policies of the network applies to the identified resource. If there are any such policies, the network gateway **104** can apply the policies to the request. For example, a policy may require that the request be dropped or redirected to an intermediate webpage.

In some cases, port numbers are used in addition to the IP addresses. For example, some applications or services on a device are only reachable through a particular port or port range. In some cases, such as in Network Address Routing (NAT), the port is effectively part of the address of a resource.

The mapping of domain names to IP addresses is generally handled by the Domain Name System, or DNS. The DNS is a hierarchical distributed naming system for computers, services, or any resource connected to the Internet or a private network. It associates information with domain names assigned to each of the participating entities. Most prominently, it translates easily memorized domain names to the numerical IP addresses needed for the purpose of locating computer services and devices worldwide. The DNS server **102** is one of the servers of the DNS. The DNS server **102** can be configured to receive DNS requests, which contain an address of a resource. The DNS server **102** can either process the request itself to find the corresponding IP address, or pass the request to another DNS server to find the corresponding IP address. With the corresponding IP address, the DNS server **102** may then respond to the DNS request with a DNS response that has the IP address that corresponds to the address in the corresponding DNS request.

Additionally, the DNS server **102** can be configured to send a mapping update **112** to the network gateway **104**. This mapping update may contain, for example, data that identifies a new resource, identifies one or more new IP addresses, and associates the new resource with one or more new IP addresses. The network gateway **104** may receive the mapping update **112** and update the data **108** to include the new resource in the set of resources, include the one or more new IP addresses in the set of one or more IP addresses, and update the associations between the set of resources and the set of IP addresses. After this updating, the network gateway **104** can use the updated data **108** to examine intercepted requests, for example to determine if a policy of the network **108** should apply to the intercepted requests.

The DNS server **102** can provide the mapping update **112** to the network gateway **104** according to any appropriate scheme. For example, the network gateway **104** may send the DNS server **104** one or more DNS requests formatted according to the traditional DNS request format. These DNS requests can include resource addresses to which a policy of the network **100** applies. In response, the DNS server **102** can respond to each DNS request with a DNS response formatted according to the traditional DNS response format. In another example, the network gateway **104** can send a message to the DNS server **102** with a list of resource addresses, and the DNS server **102** can respond with a response with a list of corresponding IP addresses. These bulk messages may be formatted according to a known or published standard, or according to a custom standard. In yet another example, the network gateway **104** can register a list of resource addresses with the

DNS server **102**. When the DNS server **102** interacts with one of those resource addresses (e.g., receiving an update to an associated IP address, responding to a DNS request of one of those resource addresses), the DNS server **102** can send the mapping update **112** to the network gateway **104**. In yet another example,

While the example shown here shows a particular configuration of elements, other configurations are possible. For example, a different data processing apparatus may be used to store the data **108** or other data. Additionally, the DNS server **102** may be outside of the network **100**. The DNS server **102** may be under the same or different administrative control as the network **100**.

FIG. **2** is a block diagram of an example updated domain name to IP address mapping. For example, the data **108** of the network gateway **104** can be updated based on the mapping update **112** from the DNS server **102**.

In this example, before the network gateway **104** receives the mapping update **112**, the network gateway **104** maintains data **108**. The data **108** includes a mapping of resources to IP addresses, including a mapping of "Example1.com" to the IP addresses IP**1**, IP**2**, and IP**3**. The DNS server **102** can send a mapping update **112** to the network gateway **104**. The mapping update **112** can include a single domain name, "Example1.com" and a single corresponding IP address, IP**9**.

The network gateway **104** can receive the mapping update **112** and modify the data **108** into data **108'** based on the mapping update **112**. In this example, the network gateway **104** can add, to the list of IP addresses associated with "Example1.com," the IP address IP**9**. For purposes of readability, the IP**9** in the data **108'** has been highlighted.

In other examples, other configurations are possible. For example, the mapping update **112** may include more than one IP address for a particular resource address and/or the mapping update **112** may include more than one resource address, each with their own or shared IP addresses.

In some configurations, the mapping update **112** may include expired mappings. That is, the mapping update **112** may also or alternatively include data identifying mappings that are no longer valid. In response to receiving such a mapping update **112**, the network gateway **104** can update the data **108** by removing an IP address from the list of IP addresses associated with a resource address.

The network gateway **104** may also update the data **108** based on other inputs. For example, the network gateway **104** may monitor DNS requests and responses to identify resource address to IP address mappings. In another example, the network gateway **104** may delete mappings that are older than a threshold age.

FIG. **3** is a block diagram of an example network **300** and a remote DNS server **302**. The network **300** includes a network gateway **304** and a client device **306**, which represents any appropriate computing devices capable of browsing resources inside or outside of the network **300**. While not shown for clarity's sake, the network **300** can include other elements including, but not limited to, wireless and/or wired access points, file and/or application servers, routers, and network cables, as well as additional client devices and network gateways.

The network **300** can be configured to route some or all of the traffic into and out of the network **300** through the gateway **304**. For example, the gateway **304** may inspect network traffic to enforce security policies, prevent malicious software from entering the network, etc. Additionally, the gateway **304** may provide directory services for the clients of the network **300** (e.g., ApacheDS, Active Directory), may apply policies (e.g., security policies) to devices on the network **300**, and may assign the client device **106** to a subnet.

To enforce the policies of the network **300**, the gateway **304** may maintain data **308** that identifies a set of one or more resources to which a policy of a network applies, identifies a set of one or more stored Internet Protocol (IP) addresses, and associates each resource in the set with one or more IP addresses in the set of IP addresses. When the network gateway **304** receives a message, for example a request from the client device **306** for a resource at an IP address of the server **310**, the network gateway **304** can determine if the IP addresses matches a stored IP address in the data **308**. If the match is found, the network gateway **304** can identify an associated resource stored in the data **308**. Once an associated resource is identified, the network gateway **304** can determine if one or more policies of the network applies to the identified resource. If there are any such policies, the network gateway **304** can apply the policies to the request. For example, a policy may require that the request be dropped or redirected an intermediate webpage.

The DNS server **302** is one of the servers of the DNS. The DNS server **302** can be configured to receive DNS requests, which contain an address of a resource. The DNS server **302** can either process the request itself to find the corresponding IP address, or pass the request to another DNS server to find the corresponding IP address. With the corresponding IP address, the DNS server **302** may then respond to the DNS request with a DNS response that has the IP address that corresponds to the address in the corresponding DNS request.

The network gateway **104** can monitor DNS traffic between the client **306** and the DNS server **302**, for example in order to update the data **108**. For example, the client **306** may generate a DNS request **312** for a resource at a domain name associated with the server **310**. The client **306** can send the DNS request **312** to the network gateway **304**. The network gateway **304** can examine the DNS request **312** and determine that the contained domain name is associated with a policy of the network. The network gateway **304** can route the DNS request **312** to the DNS server **302** which can, in response, generate a DNS response **314** that contains an IP address of the server **310**. The network gateway **304** can receive the DNS response **314** and store, in the data **108**, the domain name of the DNS request **312** and the IP address of the DNS response **314**. The network gateway **304** can send the DNS response **314** to the client **308**. The client **308**, after receiving the DNS response **314**, can generate a hypertext transfer protocol (HTTP) request **316**. The HTTP request **316** can include the IP address contained in the DNS response **314**, the same IP address that the network gateway **304** may have added to the data **108**.

The client **306** can send the HTTP request **316** to the network gateway **304** to route the HTTP request **316** to the server **310**. The network gateway **304** can, before routing the HTTP request **316** to the server **310**, examine the HTTP request **316** to determine if a policy of the network **300** applies to the HTTP request **316**. For example, the network gateway **304** can compare the IP address of the HTTP request **316** to the IP addresses stored in the data **308**. If the IP address matches, the network gateway **304** can identify one or more resource names associated with the IP address. From the identified resource names, the network gateway **304** can identify one or more policies of the network **300** and apply the identified policies to the HTTP request **316**. In some example, these policies may include logging the HTTPs request **316**, modifying a portion of the HTTP request **316**, redirecting the HTTP request **316**, or any other appropriate action.

While the example shown here shows a particular configuration of elements, other configurations are possible. For example, a different data processing apparatus may be used to store the data **308** or other data. Additionally, the DNS server **302** may be inside of the network **300**. The DNS server **302** may be under the same or different administrative control as the network **300**.

FIG. **4** is a block diagram of an example updated domain name to IP address mapping. For example, the data **308** of the network gateway **304** can be updated based on the DNS response **314** from the DNS server **102**.

In this example, before the network gateway **304** receives the DNS response **314**, the network gateway **304** maintains data **308**. The data **308** includes a mapping of resources to IP addresses, including a mapping of "Example1.com" to the IP addresses IP**1**, IP**2**, and IP**3**. The DNS server **302** can send DNS response to the client **306** via the network gateway **304**. The DNS response **314** can include a single domain name, "Example1.com" and a single corresponding IP address, IP**9**.

The network gateway **304** can receive the DNS response **314** and modify the data **308** into data **308'** based on the DNS response **314**. In this example, the network gateway **304** can add, to the list of IP addresses associated with "Example1.com," the IP address IP**9**. For purposes of readability, the IP**9** in the data **308'** has been highlighted.

In other examples, other configurations are possible. In this example, the DNS response **314** is used to update the data **308** and the DNS request **312** is not used. However, in some other examples, both the DNS request **312** and the DNS response **314** may be used. In another example, a service other than the DNS is used to discover mappings between resource addresses and IP addresses, and messages of that resource may be used.

FIG. **5** is a block diagram of an example network **500** that is applying a policy to a request. The example network **500** applies some policies of the network **500** by routing some network traffic through a man-in-the-middle (MitM) gateway. Other configurations for applying policies of networks are possible, including those that do not use a MitM gateway.

The network **500** includes a network gateway **502** and a MitM gateway **504**. Also shown in the network **500** is a client device **506**, which represents any appropriate computing device capable of browsing resources outside of the network **500**. While not shown for clarity's sake, the network **500** can include other elements including, but not limited to, wireless and/or wired access points, file and/or application servers, routers, and network cables, as well as additional client devices **506**, network gateways **502**, and/or MitM gateways **504**.

The network **500** can be configured to route some or all of the messages addressed outside the network to the network gateway **502**. The network gateway **502** can inspect the messages and, optionally, modify or drop some messages. For example, the network gateway **502** may be configured to prevent traffic flow from a particular class of application (e.g., chat, files sharing). The network gateway **502** may also be configured to intercept messages intended for a recipient outside of the network **500** and reply directly. This process is sometimes referred to as spoofing.

For example, the network gateway **502** may intercept and examine a HTTP request **508** from the client device **506** that is addressed, by IP address, to a resource on the server **518**. Based on, for example, data **503**, the network gateway **502** may determine that a policy of the network **500** applies to the HTTP request **508**. The data **503** may, for example, identify a set of one or more resources to which a policy of a network **500** applies, identify a set of one or more stored Internet Protocol (IP) addresses, and associate each resource in the set with one or more IP addresses in the set of IP addresses.

In response to determining that a policy of the network **500** applies to the HTTP request **508**, the network gateway **502** may issue a redirect with the address of the MitM gateway **504** to the client device **506**. Many types of redirections are possible, including but not limited to **402** HTTP redirects, server-side scripting, frame redirects, and Apache mod_rewrites.

The network gateway **502** may make the determination to pass communication through the MitM gateway **504** based on security policies or concerns as applied to the network **500**. While passing communication through the MitM gateway **504** may provide some other benefits (e.g., caching of frequently visited resources or to reduce bandwidth usages), the network gateway **502** may be conjured to primarily, exclusively, or only partially account for security considerations of passing communication through the network gateway **502** or the MitM gateway **504**.

The client device **506**, upon receiving the MitM gateway address **512**, can initialize a connection, such a cryptographic connection **514**, with the MitM gateway **504** at the MitM gateway address **512**. The cryptographic connection **514** may be an SSL, TLS, or any other appropriate cryptographic session. The MitM gateway **504** may then initialize another cryptographic connection **516** with the server **518** that hosts the resource in the HTTP request **508**.

Once the cryptographic connections **514** and **516** are established, the client device **506** and the server **518** may communicate with each other. In this communication, the MitM gateway **504** may act as a proxy of the server **518** for the client device **506** and as a proxy of the client device **506** for the server **518**. The MitM gateway **504** is thus able to receive an encrypted message from the client device **506**, decrypt the message, inspect the message, optionally alter or drop the message, encrypt the possibly altered message into a second encrypted form, and pass the message to the server **518**. The MitM gateway **504** may perform the same type of reception, decryption, inspection, alteration or drop, encryption, and passage with messages from the server **518** to the client device **506**. The MitM gateway **504** may sometimes be referred to by other terms including, but not limited to, a reverse proxy, intercepting proxy, accelerator, accelerating proxy, and transparent proxy.

FIG. **6** is a swim-lane diagram of an example process **600** for keeping a mapping of domain names to IP addresses. The process **300** is described with reference to a particular set of components. However, other components, including and not limited the components of FIGS. **2-5**, can be used to perform the process **600** or a similar process.

A DNS server **606** generates a mapping update and sends the mapping update to a network gateway **604** (**610**). For example, the DNS server can generate a mapping update that contains data that identifies a new resource, that identifies one or more new IP addresses, and that associates the new resource with one or more new IP addresses. The mapping update my take the format of established messages, such as a DNS response, or may take a custom format. The DNS server **606** may generate and send the mapping update in response to an input (e.g., a request from the network gateway **604**), at regular or irregular intervals (e.g., daily, when system resources are free) or on another schedule.

The network gateway **604** receives the mapping update and updates stored data (**612**). For example, the network gateway **604** may maintain data that identifies a set of one or more resources to which a policy of a network applies, and identifies a set of one or more stored Internet Protocol (IP)

addresses, and associates each resource in the set with one or more IP addresses in the set of IP addresses. The network gateway can examine the mapping update to determine if any of the contents are not already stored in the data of the gateway. If any of the contents are new, the network gateway can update the stored data to include the new resource, the new IP address or addresses, and/or update the associations to add in the contents of the mapping update.

A client device **602** generates and sends a DNS request for a resource address to the DNS server **606** (**614**). For example, a user of the client device **602** may enter a uniform resource locator (URL) address into an address bar of a web browser application. In response, the web browser application can generate a DNS request with the entered URL and send the DNS request to the DNS server, via the network gateway **604**.

The network gateway **604** logs the DNS request and routes the DNS request to the DNS server **606** (**616**). For example, before, after, or as the network gateway **604** routes the DNS request to the DNS server **606**, the network gateway **604** can log the DNS request. This log may include, for example, an identifier of the client device **602**, the URL of the request, a timestamp, or other appropriate data.

The DNS server **606** receives the DNS request and looks up an IP address matching the requested resource address (**618**), and the DNS server **606** returns the IP address to the client device **602** (**620**). For example, the DNS server may query another DNS server for an IP address that matches the URL in the request, and may generate a DNS response with that IP address.

The network gateway **604** logs the DNS response and routes the DNS response to the client device **602** (**622**). For example, before, after, or as the network gateway **604** routes the DNS response to the client device **602**, the network gateway **604** can log the DNS request. This log may include, for example, an identifier of the client device **602**, the URL of the request, the IP address of the response, a time to live (TTL) value, a timestamp, or other appropriate data. The client device receives the IP address in the DNS response (**624**).

The network gateway updates the stored data (**626**). For example, the network gateway **604** can match the DNS response with the DNS request in order to update the stored data, or can use the data contained within the DNS response to update the stored data. The network gateway can, for example, determine if the data from the DNS messages contains a resource, IP address, or mapping that is not already stored. In response, the network gateway **604** can update the set of resources with the DNS message's resource, the set of IP addresses with the DNS message's IP address, and/or update the associations between the resources and the set of IP addresses.

The client device generates and sends an HTTP request to the IP address (**628**). For example, in response to receiving the DNS response (**624**), the web browser of the client device **602** can generate an HTTP request that requests the resource at the IP address returned by the DNS response. In some cases, this request may be a hypertext transport protocol secure (HTTPS) request or another type of encrypted request.

The network gateway **604** intercepts the HTTP request and applies a policy of the network to the HTTTP request (**630**). The server **608** receives the HTTP request (**632**) and returns the requested resource (**634**). The network gateway **604** intercepts the return message and applies a policy of the network (**636**). The client device **602** receives the requested resource (**638**).

For example, the network gateway can intercept the HTTP request and HTTP response and compare the IP address with the stored IP addresses in the network gateway **604**. If there is a match, the network gateway **604** can identify a particular resource in the set of stored resources that is associated with the requested IP address, and identify a particular policy, or policies, associated with the particular resource. The network gateway **604** can apply the identified policy or policies to the HTTP request.

The network gateway **604** may determine that the IP address is shared by two domains (e.g., a file hosting service and web email client service offered by the same company). One policy of the network specifies that all email traffic should be logged, and another policy of the network specifies that all file hosting traffic should be checked for malicious code. In this example, the HTTP request can be logged. Later, when a corresponding HTTP response is intercepted by the network gateway, the HTTP response can be logged and checked for malicious code.

Although a particular number, type, and order of operations are shown here, other numbers, types, and orders of operations are possible. For example, if the policy to apply to the HTTP request requires that the HTTP request be blocked, the network gateway **604** may be configured to drop the HTTP request instead of routing the HTTP request to the server **608**. In some examples, only requests that have an applied policy are inspected. For example, the network gateway **604** may be configured such that the only messages that are inspected for policy application are those with an IP address that matches a stored IP address in the network gateway **604**.

FIG. **7** is a schematic diagram that shows an example of a computing system **700**. The computing system **700** can be used for some or all of the operations described previously, according to some implementations. The computing system **700** includes a processor **710**, a memory **720**, a storage device **730**, and an input/output device **740**. Each of the processor **710**, the memory **720**, the storage device **730**, and the input/output device **740** are interconnected using a system bus **750**. The processor **710** is capable of processing instructions for execution within the computing system **700**. In some implementations, the processor **710** is a single-threaded processor. In some implementations, the processor **710** is a multi-threaded processor. The processor **710** is capable of processing instructions stored in the memory **720** or on the storage device **730** to display graphical information for a user interface on the input/output device **740**.

The memory **720** stores information within the computing system **700**. In some implementations, the memory **720** is a computer-readable medium. In some implementations, the memory **720** is a volatile memory unit. In some implementations, the memory **720** is a non-volatile memory unit.

The storage device **730** is capable of providing mass storage for the computing system **700**. In some implementations, the storage device **730** is a computer-readable medium. In various different implementations, the storage device **730** may be a floppy disk device, a hard disk device, an optical disk device, or a tape device.

The input/output device **740** provides input/output operations for the computing system **700**. In some implementations, the input/output device **740** includes a keyboard and/or pointing device. In some implementations, the input/output device **740** includes a display unit for displaying graphical user interfaces.

Some features described can be implemented in digital electronic circuitry, or in computer hardware, firmware, software, or in combinations of them. The apparatus can be implemented in a computer program product tangibly embodied in an information carrier, e.g., in a machine-readable storage device, for execution by a programmable proces-

sor; and method steps can be performed by a programmable processor executing a program of instructions to perform functions of the described implementations by operating on input data and generating output. The described features can be implemented advantageously in one or more computer programs that are executable on a programmable system including at least one programmable processor coupled to receive data and instructions from, and to transmit data and instructions to, a data storage system, at least one input device, and at least one output device. A computer program is a set of instructions that can be used, directly or indirectly, in a computer to perform a certain activity or bring about a certain result. A computer program can be written in any form of programming language, including compiled or interpreted languages, and it can be deployed in any form, including as a stand-alone program or as a module, component, subroutine, or other unit suitable for use in a computing environment.

Suitable processors for the execution of a program of instructions include, by way of example, both general and special purpose microprocessors, and the sole processor or one of multiple processors of any kind of computer. Generally, a processor will receive instructions and data from a read-only memory or a random access memory or both. The essential elements of a computer are a processor for executing instructions and one or more memories for storing instructions and data. Generally, a computer will also include, or be operatively coupled to communicate with, one or more mass storage devices for storing data files; such devices include magnetic disks, such as internal hard disks and removable disks; magneto-optical disks; and optical disks. Storage devices suitable for tangibly embodying computer program instructions and data include all forms of non-volatile memory, including by way of example semiconductor memory devices, such as EPROM (erasable programmable read-only memory), EEPROM (electrically erasable programmable read-only memory), and flash memory devices; magnetic disks such as internal hard disks and removable disks; magneto-optical disks; and CD-ROM (compact disc read-only memory) and DVD-ROM (digital versatile disc read-only memory) disks. The processor and the memory can be supplemented by, or incorporated in, ASICs (application-specific integrated circuits).

To provide for interaction with a user, some features can be implemented on a computer having a display device such as a CRT (cathode ray tube) or LCD (liquid crystal display) monitor for displaying information to the user and a keyboard and a pointing device such as a mouse or a trackball by which the user can provide input to the computer.

Some features can be implemented in a computer system that includes a back-end component, such as a data server, or that includes a middleware component, such as an application server or an Internet server, or that includes a front-end component, such as a client computer having a graphical user interface or an Internet browser, or any combination of them. The components of the system can be connected by any form or medium of digital data communication such as a communication network. Examples of communication networks include, e.g., a LAN (local area network), a WAN (wide area network), and the computers and networks forming the Internet.

The computer system can include clients and servers. A client and server are generally remote from each other and typically interact through a network, such as the described one. The relationship of client and server arises by virtue of computer programs running on the respective computers and having a client-server relationship to each other.

This document describes technologies that can be applied to a wide range of uses, which are designed and intended to be beneficial for all users involved. However, some of the technologies described may be put to illegitimate, malicious, and even illegal ends by bad actors. This is true with almost any technology, but there is often a greater sensitivity when a technology interacts with a user's security and private information. The described technologies all are designed to operate in an environment and in a manner that respects the rights of all users. As such, features such as user notification, opt-in and opt-out procedures, and privacy settings are available options to be used to ensure user security and privacy are respected.

What is claimed is:

1. A method performed by data processing apparatus, the method comprising: maintaining information including (i) a set of one or more resources to which a network policy applies, and (ii) a set of one or more Internet Protocol (IP) addresses, wherein each resource is associated with one or more of the IP addresses; monitoring domain name service (DNS) responses; generating, from the monitored DNS responses, data identifying (i) a new resource, or (ii) one or more new IP addresses, or (iii) both a new resource and one or more new IP addresses, wherein each new IP address is associated with either a resource in the set of one or more resources, or the new resource; updating the maintained information based on the data received from the DNS; receiving a request from a client device on the network for a requested resource identified by a requested IP address; determining that the requested IP address matches one of the IP addresses in the set of one or more IP addresses; identifying a particular resource associated with the matched IP address; identifying a particular network policy applies; and applying the identified particular network policy to the received request, wherein the data processing apparatus comprise a plurality of hardware devices, each hardware device including a separate processor and memory unit; wherein a first hardware device is configured to: route traffic to and from client devices on the network into and out of the network; and maintain information including (i) a set of one or more resources to which a network policy applies, and (ii) a set of one or more Internet Protocol (IP) addresses, wherein each resource is associated with one or more of the IP addresses; monitor DNS responses; generate, from the monitored DNS responses, data identifying (i) a new resource, or (ii) one or more new IP addresses, or (iii) both a new resource and one or more new IP addresses, wherein each new IP address is associated with either a resource in the set of one or more resources, or the new resource; update the maintained information based on the data received from the DNS; receive a request from a client device on the network for a requested resource identified by a requested IP address; determine that the requested IP address matches one of the IP addresses in the set of one or more IP addresses; identify a particular resource associated with the matched IP address; identify a particular network policy; and wherein a second hardware device is configured to apply the identified particular network policy to the request.

2. The method of claim **1**, wherein to apply the identified particular network policy to the request, the data processing apparatus are configured to inspect communication between the client and a server serving the requested resource.

3. The method of claim **1**, wherein only requests that have an applied policy are inspected.

4. The method of claim **1**, wherein the DNS server is hosted on the network.

5. The method of claim 1, wherein the DNS server is under the same administrative control as the network.

6. The method of claim 1, the method further comprising: receiving, from a DNS server, data identifying (i) a new resource, or (ii) one or more new IP addresses, or (iii) both a new resource and one or more new IP addresses, wherein each new IP address is associated with either a resource in the set of one or more resources, or the new resource; and updating the maintained information based on the data generated from the DNS responses.

7. The method of claim 6, wherein the DNS responses are received from DNS servers outside of the network.

8. The method of claim 1, wherein the resource is identified in the information by the resource's Uniform Resource Locator (URL).

9. A system comprising: one or more processors configured to execute computer program instructions; and computer storage media encoded with computer program instructions that, when executed by one or more processors, cause data processing apparatus to perform operation comprising: maintaining information including (i) a set of one or more resources to which a network policy applies, and (ii) a set of one or more Internet Protocol (IP) addresses, wherein each resource is associated with one or more of the IP addresses; monitoring DNS responses; generating, from the monitored DNS responses, data identifying (i) a new resource, or (ii) one or more new IP addresses, or (iii) both a new resource and one or more new IP addresses, wherein each new IP address is associated with either a resource in the set of one or more resources, or the new resource; updating the maintained information based on the data received from the DNS; receiving a request from a client device on the network for a requested resource identified by a requested IP address; determining that the requested IP address matches one of the IP addresses in the set of one or more IP addresses; identifying a particular resource associated with the matched IP address; identifying a particular network policy applies; and applying the identified particular network policy to the received request, wherein the data processing apparatus comprise a plurality of hardware devices, each hardware device including a separate processor and memory unit; wherein a first hardware device is configured to: route traffic to and from client devices on the network into and out of the network; and maintain information including (i) a set of one or more resources to which a network policy applies, and (ii) a set of one or more Internet Protocol (IP) addresses, wherein each resource is associated with one or more of the IP addresses; monitor DNS responses; generate, from the monitored DNS responses, data identifying (i) a new resource, or (ii) one or more new IP addresses, or (iii) both a new resource and one or more new IP addresses, wherein each new IP address is associated with either a resource in the set of one or more resources, or the new resource; update the maintained information based on the data received from the DNS; receive a request from a client device on the network for a requested resource identified by a requested IP address; determine that the requested IP address matches one of the IP addresses in the set of one or more IP addresses; identify a particular resource associated with the matched IP address; identify a particular network policy; and wherein a second hardware device is configured to apply the identified particular network policy to the request.

10. The system of claim 9, wherein to apply the identified particular network policy to the request, the data processing apparatus are configured to inspect communication between the client and a server serving the requested resource.

11. The system of claim 9, wherein only requests that have an applied policy are inspected.

12. The system of claim 9, wherein the DNS server is hosted on the network.

13. The system of claim 9, wherein the DNS server is under the same administrative control as the network.

14. The system of claim 9, the operations further comprising: receiving, from a DNS server, data identifying (i) a new resource, or (ii) one or more new IP addresses, or (iii) both a new resource and one or more new IP addresses, wherein each new IP address is associated with either a resource in the set of one or more resources, or the new resource; and updating the maintained information based on the data generated from the DNS responses.

15. The system of claim 14, wherein the DNS responses are received from DNS servers outside of the network.

16. The system of claim 9, wherein the resource is identified in the information by the resource's Uniform Resource Locator (URL).

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